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Invention: LIQUID CRYSTAL DISPLAY DEVICE

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SPECIFICATION

LIQUID CRYSTAL DISPLAY DEVICE

BACKGROUND OF THE INVENTION

The present invention relates to a liquid crystal display device, and more particularly, it relates to a transmission/reflection type liquid crystal display device capable of display in both a transmission mode and a reflection mode.

Owing to their characteristics such as a small thickness and small power consumption, liquid crystal display devices are recently widely used in OA equipment such as a word processor and a personal computer, portable information equipment such as an electronic notebook and a camera-integrated VTR equipped with a liquid crystal monitor.

The liquid crystal display devices are divided roughly into two types: reflection type and transmission type. A liquid crystal display device is not a spontaneously luminous display device like a CRT (cathode-ray tube) and EL (electroluminescence), but light of a lighting device disposed behind a liquid crystal display panel (known as the so-called back light) is used for display in a transmission type liquid crystal display device and ambient light is used for display in a reflection type liquid crystal display device.

Since a transmission type liquid crystal display displays an image by using light from a back light, it can advantageously

display bright images with a high contrast ratio without being affected by ambient brightness but disadvantageously consumes large power due to the back light included therein. A back light consumes approximately 50% or more of the power consumption in a general transmission type liquid crystal display device. Furthermore, in a very bright environment (for example, in the open air in fine weather), the visibility is degraded or the power consumption is further increased when the brightness of the back light is increased to attain sufficient visibility.

On the other hand, since a reflection type liquid crystal display device does not include a back light, it advantageously consumes very small power, but the brightness and the contrast ratio of display are disadvantageously largely affected by the environment such as ambient brightness. In particular, in a dark environment, the visibility is excessively degraded.

For the purpose of overcoming these problems, a liquid crystal display device having a function to display images in both the reflection mode and the transmission mode is disclosed in, for example, Japanese Laid-Open Patent Publication No. 11-101992.

This transmission/reflection type liquid crystal display device includes, in every pixel region, a reflection pixel electrode for reflecting ambient light and a transmission pixel electrode for transmitting light from a back light, so that images can be displayed with the mode switched between the transmission mode and the reflection mode or in the both modes. Accordingly,

the transmission/reflection type liquid crystal display device has both the characteristic of a reflection type liquid crystal display device, that is, the small power consumption, and the characteristic of a transmission type liquid crystal display device, that is, bright display with a high contrast ratio minimally affected by ambient brightness. Moreover, the disadvantage of a transmission type liquid crystal display device that the visibility is degraded in a very bright environment (for example, in the open air in fine weather) can be suppressed.

The transmission/reflection type liquid crystal display device disclosed in Japanese Laid-Open Patent Publication No. 11-101992, however, has irregularities of the surface profile of the reflection electrode for increasing the brightness of display in the reflection mode (as is understood from, for example, FIGS. **6** and **9** of the publication). Accordingly, the thickness of a liquid crystal layer is largely varied in a reflection region, and hence, it is difficult to realize optimal display. Furthermore, it is necessary to precisely control the shape of the irregularities (convexes/concaves) for preventing light interference caused by the irregularities, which disadvantageously increases the fabrication cost.

SUMMARY OF THE INVENTION

An object of the invention is providing a transmission/reflection type liquid crystal display device

capable of realizing high quality display in which the thickness of a liquid crystal layer, in a reflection region in particular, can be precisely controlled.

The object is achieved by the following liquid crystal display device. The liquid crystal display device of this invention includes a first substrate; a second substrate; a liquid crystal layer disposed between the first substrate and the second substrate; and a plurality of pixel regions for display, and each of the plurality of pixel regions includes a transmission region for display in a transmission mode using light entering through the first substrate and a reflection region for display in a reflection mode using light entering through the second substrate, the first substrate includes, on a surface thereof facing the liquid crystal layer, a transparent electrode region defining the transmission region and a reflection electrode region defining the reflection region, and each surface facing the liquid crystal layer of the transparent electrode region and the reflection electrode region of the first substrate are flat, and the second substrate includes a light diffusion layer in the reflection region and includes, on a surface thereof facing the liquid crystal layer, a transparent electrode in the reflection region and the transmission region, and the surface thereof facing the liquid crystal layer is flat in the transmission region and the reflection region.

The first substrate (a substrate disposed on a side closer

to a back light, such as an active matrix substrate) and the second substrate (a substrate disposed on a side closer to an observer, such as a color filter substrate) included in the present liquid crystal display device have flat surfaces facing the liquid crystal layer in the reflection region and the transmission region, and hence, the liquid crystal layer has a constant thickness in each of the reflection region and the transmission region. Accordingly, the thicknesses of the liquid crystal layer in the reflection region and the transmission region can be set optimally to the respective display modes. The light diffusion layer provided on the second substrate in the reflection region diffuses light entering the reflection region, so as to realize paper white display.

The word "being flat" herein means a surface state for making the thickness of the liquid crystal layer uniform so as not to cause degradation in display quality derived from variation in the thickness of the liquid crystal layer. Specifically, when roughness (for example, an average value of height differences of the irregularities measured with a surface roughness meter) of a surface in a given region is smaller than 1/10 of the thickness of the liquid crystal layer in the region, the surface can be regarded as being flat. A flat surface is not always a mirror surface.

The second substrate may include the light diffusion layer also in the transmission region, or the second substrate may include the light diffusion layer in the reflection region alone. When the light diffusion layer is formed in the transmission region

of the second substrate, light passing through the transmission region is diffused so as to suppress surface reflection in the transmission region of the liquid crystal display device. As a result, display free from unevenness and glare can be realized. In other words, a portion of the light diffusion layer formed in the transmission region exhibits the so-called anti-glare effect. On the other hand, when the light diffusion layer is not formed in the transmission region, the optical efficiency can be improved in the transmission region. It can be appropriately determined depending upon the application of the liquid crystal display device which configuration is employed.

The second substrate may include a transparent substrate, and the light diffusion layer may be provided on a surface of the transparent substrate facing the liquid crystal layer or formed on a surface of the transparent substrate closer to an observer (namely, on a surface not facing the liquid crystal layer). It can be appropriately determined which configuration is employed depending upon the application of the liquid crystal display device in consideration of advantages and disadvantages of the respective configurations described below.

In the configuration where the light diffusion layer is provided on the surface facing the liquid crystal layer, blur (unclearness of contours) of a displayed image is advantageously minimally caused, but the fabrication process is complicated and the cost is increased. In the configuration where the light

diffusion layer is selectively formed in the reflection region, when the pitch of patterns of disposing the light diffusion layer is close to the pixel pitch, there arises a problem that interference of light (moiré) is easily caused. This problem is conspicuous in a highly refined liquid crystal display device.

On the other hand, the configuration where the light diffusion layer is provided on the surface closer to an observer can be advantageously easily fabricated, easily applied to design change or common use of the light diffusion layer and fabricated at low cost, but blur of a displayed image tends to be caused. In order to suppress blur of a displayed image, a thinner substrate is preferred. A problem of double image due to the thickness of the substrate is never caused in disposing the light diffusion layer on either surface of the substrate differently from a case of disposing a reflection layer. This is because the light diffusion layer does not directly reflect incident light differently from the reflection layer.

The liquid crystal display device may further include a polarizing plate provided on a surface of the second substrate closer to the observer, and when the light diffusion layer is provided on the surface closer to the observer, the light diffusion layer is preferably provided between the transparent substrate and the polarizing plate. When the light diffusion layer is provided between the transparent substrate and the polarizing plate, blur of a displayed image can be minimized. Furthermore, the light

diffusion layer preferably functions as an adhesive layer for adhering the transparent substrate and the polarizing plate to each other. When an adhesive for adhering the polarizing plate onto the transparent substrate is formed from a material having a light diffusing function, the fabrication process can be simplified.

The light diffusion layer is preferably a dispersion type light diffusion layer containing a matrix material and particles having a refractive index different from that of the matrix material. When the light diffusion layer is formed from the material obtained by dispersing the particles in the matrix material, the light diffusion layer can be easily formed to have a flat surface as well as the thickness of the liquid crystal layer in the reflection region can be easily and accurately controlled.

The second substrate may include a transparent substrate and a color filter layer, and the color filter layer may function also as the light diffusion layer. When the matrix material where the particles with a different refractive index from the matrix material are dispersed is used for forming the color filter layer, the color filter layer can function also as the light diffusion layer, and thus, the fabrication process of the liquid crystal display device can be simplified.

The second substrate may include a plastic substrate, the plastic substrate may contain a matrix material and particles having a refractive index different from that of the matrix material,

and the plastic substrate may function also as the light diffusion layer. When the matrix material where the particles with a different refractive index from the matrix material are dispersed is used for forming the plastic substrate, the plastic substrate can function also as the light diffusion layer, and thus, the fabrication process of the liquid crystal display device can be simplified.

A thickness of the liquid crystal layer in the reflection region is preferably about 1/2 of a thickness of the liquid crystal layer in the transmission region. In a liquid crystal display device operated in a display mode using polarization (hereinafter simply referred to as the polarization mode), when the thickness of the liquid crystal layer in the reflection region is 1/2 of the thickness of the liquid crystal layer in the transmission region, retardation of light passing through the reflection region can accord with retardation of light passing through the transmission region. Furthermore, the liquid crystal layer has a constant thickness in each region. As a result, high quality display can be realized.

The liquid crystal display device may further include an anti-glare layer provided on a surface of the second substrate closer to an observer. In the liquid crystal display device including the anti-glare layer on the surface of the second substrate closer to an observer, since the light diffusion layer is provided on the second substrate, light entering from the back

light and passing through the transmission region and light entering from the side closer to the observer, reflected by the reflection electrode region and passing through the reflection region both pass through the light diffusion layer to be diffused by the light diffusion layer before going out toward the observer. Accordingly, moiré cause between irregularities of the anti-glare layer and the pixel regions, moiré caused between the irregularities of the anti-glare layer and the transmission regions and moiré caused between the irregularities of the anti-glare layer and the reflection regions are all suppressed, resulting in realizing display free from unevenness.

When the liquid crystal display device includes the anti-glare layer provided on the surface of the second substrate closer to an observer, the second substrate may include a transparent substrate, and the light diffusion layer is preferably provided between the transparent substrate and the anti-glare layer. When the light diffusion layer is provided between the transparent substrate and the anti-glare layer, the effect to suppress moiré is remarkably exhibited. When the liquid crystal display device further include a polarizing plate between the transparent substrate and the anti-glare layer, the light diffusion layer is preferably provided between the transparent substrate and the polarizing plate. When the light diffusion layer is provided between the transparent substrate and the polarizing plate, blur of a displayed image can be suppressed.

BRIEF DESCRIPTION OF THE DRAWINGS

FIGS. **1A** and **1B** are schematic cross-sectional views of liquid crystal display devices **100** and **100'** according to Embodiment 1 of the invention, respectively;

FIG. **2** is a schematic plan view of an active matrix substrate **100A** included in the liquid crystal display devices **100** and **100'** of Embodiment 1;

FIGS. **3A**, **3B** and **3C** are schematic cross-sectional views for showing exemplified arrangement of a light diffusion layer **30** used in the liquid crystal display devices of Embodiment 1;

FIGS. **4A** and **4B** are schematic cross-sectional views of other liquid crystal display devices **200** and **200'** according to Embodiment 1 of the invention, respectively;

FIG. **5** is a schematic cross-sectional view of another liquid crystal display device **300** according to Embodiment 1 of the invention;

FIG. **6** is a schematic cross-sectional view of still another liquid crystal display device **400** according to Embodiment 1 of the invention;

FIG. **7** is a schematic cross-sectional view of still another liquid crystal display device **500** according to Embodiment 1 of the invention;

FIG. **8** is a schematic cross-sectional view of still another liquid crystal display device **600** according to Embodiment 1 of the invention;

FIG. **9** is a schematic cross-sectional view of still another liquid crystal display device **700** according to Embodiment 1 of the invention;

FIG. **10** is a schematic cross-sectional view of still another liquid crystal display device **800** according to Embodiment 1 of the invention;

FIG. **11** is a schematic cross-sectional view of still another liquid crystal display device **900** according to Embodiment 1 of the invention;

FIGS. **12A** and **12B** are schematic cross-sectional views of liquid crystal display devices **1000** and **1000'** according to Embodiment 2 of the invention, respectively;

FIG. **13** is a schematic cross-sectional view of another liquid crystal display device **1100** according to Embodiment 2 of the invention;

FIG. **14** is a schematic cross-sectional view of still another liquid crystal display device **1200** according to Embodiment 2 of the invention;

FIG. **15** is a schematic cross-sectional view of a liquid crystal display device **1300** according to Embodiment 3 of the invention;

FIG. **16** is a schematic cross-sectional view of another liquid crystal display device **1400** according to Embodiment 3 of the invention;

FIG. **17** is a top view for schematically showing arrangement

of a transmission region **Tr** and a reflection region **Rf** in a pixel region **Px** of the liquid crystal display device **1300** or **1400** of Embodiment 3;

FIG. **18** is a top view for schematically showing another arrangement of the transmission region **Tr** and the reflection region **Rf** in the pixel region **Px** of the liquid crystal display device **1300** or **1400** of Embodiment 3; and

FIG. **19** is a top view for schematically showing still another arrangement of the transmission region **Tr** and the reflection region **Rf** in the pixel region **Px** of the liquid crystal display device **1300** or **1400** of Embodiment 3.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Preferred embodiments of the invention will now be described with reference to the accompanying drawings. It is noted that the invention is not limited to the following embodiments.

EMBODIMENT 1

In a liquid crystal display device of Embodiment 1, a light diffusion layer is disposed on the inside (on a side closer to a liquid crystal layer) of a second substrate (disposed on a side closer to an observer) opposing a first substrate (disposed on a side closer to a back light) with the liquid crystal layer sandwiched therebetween.

FIGS. **1A** and **1B** respectively show the schematic sectional structures of liquid crystal display devices **100** and **100'** of this

embodiment. FIGS. **1A** and **1B** are cross-sectional views of the liquid crystal display devices **100** and **100'** of this embodiment, and FIG. **2** is a plan view of an active matrix substrate **100A** used in the liquid crystal display devices **100** and **100'**.

Each of the transmission/reflection type liquid crystal display devices **100** and **100'** includes, as is shown in FIGS. **1A** and **1B**, a transmission region **Tr** and a reflection region **Rf** in each of plural pixel regions **Px** arranged in the form of a matrix, so as to display images in a transmission mode and a reflection mode. Images can be displayed in one of the transmission mode and the reflection mode or in both the modes. Typically, each of the liquid crystal display devices **100** and **100'** includes a pair of polarizing plates (not shown) disposed in a parallel Nicols manner and a lighting device (back light) (not shown) disposed on the side of the active matrix substrate **100A**. Each of FIGS. **1A** and **1B** shows one pixel region **Px**. The liquid crystal display device **100'** shown in FIG. **1B** is different from the liquid crystal display device **100** of FIG. **1A** in the structure of a light diffusion layer **30**.

As is shown in FIG. **1A**, the liquid crystal display device **100** includes the active matrix substrate **100A**, a counter substrate (also known as a "color filter substrate") **100B** and a liquid crystal layer **24** sandwiched therebetween.

The active matrix substrate **100A** includes, as is shown in FIG. **2**, a transparent electrode region **20** for defining a

transmission region **Tr** of the liquid crystal display device **100** and a reflection electrode region **22** for defining a reflection region **Rf**. One pixel region **Px** includes the transmission region **Tr** and the reflection region **Rf**, and one pixel electrode region **1** includes the transparent electrode region **20** and the reflection electrode region **22**. The pixel electrode region **1**, the transparent electrode region **20** and the reflection electrode region **22** are defined as regions of the active matrix substrate **100A**, and the pixel region **Px**, the transmission region **Tr** and the reflection region **Rf** are defined as regions of the liquid crystal display device **100**.

The transparent electrode region **20** includes a transparent electrode **21**, and the reflection electrode region **22** includes a metal layer **23**. The metal layer **23** is formed to be in contact with the transparent electrode **21**, and is electrically connected to a drain electrode **16** of a TFT **4** through the transparent electrode **21** so as to function as a reflection electrode. In other words, the transparent electrode **21** and the metal layer **23** together function as a pixel electrode. The transparent electrode **21** is formed from a transparent conducting material such as ITO, and the metal layer **23** is formed from a metal having high reflectance such as Al.

In general, the metal layer **23** defining the reflection electrode region **22** is not necessarily electrically connected to the drain electrode **16**, and the metal layer **23** itself does not

necessarily function as the reflection electrode. For example, an insulating layer (not shown) may be disposed below the metal layer **23**, so as to apply a voltage to the liquid crystal layer **24** within the reflection region **Rf** by using a separately formed transparent electrode.

As is shown in FIG. **1A**, the active matrix substrate **100A** includes a transparent insulating substrate **11** such as a glass substrate, and a gate line **2**, a gate electrode **12** and an auxiliary capacitor electrode **8** are formed on the transparent substrate **11**. The active matrix substrate **100A** further includes a gate insulating film **7** covering the gate line **2**, the gate electrode **12** and the auxiliary capacitor electrode **8**. On a portion of the gate insulating film **7** above the gate electrode **12**, a semiconductor layer **13**, a channel protection layer **14**, a source electrode **15** and the drain electrode **16** are formed so as to together constitute the TFT **4**. The source electrode **15** and the drain electrode **16** of the TFT **4** are electrically connected to a source line **3** and a connection electrode **5**, respectively. Each of the source line **3** and the connection electrode **5** has a two-layer structure including a transparent conducting layer **17** and a metal layer **18**.

An interlayer insulating film **19** is formed so as to substantially cover the surface of the transparent substrate **11** bearing the TFT **4**, and the interlayer insulating film **19** is planarized. On the planarized surface of the interlayer insulating film **19**, the transparent electrode **21** is formed, and

on the transparent electrode **21**, the metal layer **23** is formed. The transparent electrode **21** is electrically connected to the connection electrode **5** through a contact hole **6** formed in the interlayer insulating film **19**, so as to be electrically connected to the drain electrode **16** through the connection electrode **5**. The metal layer **23** is electrically connected to the drain electrode **16** through the transparent electrode **21**.

Since the interlayer insulating film **19** is thus formed, the surface of the substrate **100A** can be flat and the metal layer **23** can be insulated from the TFT **4** and the various lines formed below the interlayer insulating film **19**. Therefore, the metal layer **23** can be formed above the TFT **4**, the gate line **2**, the source line **3** and the connection electrode **5**, resulting in increasing the display area.

The active matrix substrate **100A** described above is merely an example, and the structures of the TFT **4** and the connection electrode **5** can be appropriately modified. Also, any of known active matrix substrates can be applied as far as the surfaces of the transparent electrode region **20** and the reflection electrode region **22** facing the liquid crystal layer **24** are flat.

The transparent electrode region **20** and the reflection electrode region **22** of the active matrix substrate **100A** are preferably entirely flat. However, there is a case that a step is formed, for example, above the contact hole **6**. In this case, if the area of a region having a different thickness is 10% or

less of the total area of the remaining region (for example, the total area of the reflection electrode region), such a step is allowable because degradation in the display quality caused by the step cannot be visually recognized.

The active matrix substrate **100A** can be fabricated by a known method from known materials. Furthermore, an alignment layer (not shown) may be formed on the surface of the active matrix substrate **100A** facing the liquid crystal layer **24** if necessary.

The counter substrate **100B** of the liquid crystal display device **100** includes, as is shown in FIG. **1A**, a transparent insulating substrate **9** of glass or the like, and a color filter layer **10** and the light diffusion layer **30** formed on the surface of the transparent insulating substrate **9** facing the liquid crystal layer **24**. The counter substrate **100B** further includes a single counter electrode (not shown) for applying a voltage to the liquid crystal layer **24** on substantially the entire surface thereof. The counter electrode is typically provided on the surface of the color filter layer **10** facing the liquid crystal layer **24**. The color filter layer **10** typically includes color layers of red (R), green (G) and blue (B) and black matrixes disposed therebetween (none shown). The color filter layer **10** and the counter electrode (not shown) can be fabricated by a known method from known materials.

The light diffusion layer **30** is formed on substantially the entire surface of the counter substrate **100B**. Specifically, the light diffusion layer **30** is formed not only in the reflection region

Rf but also in the transmission region **Tr** of the counter substrate **100B**.

A portion of the light diffusion layer **30** formed in the reflection region **Rf** diffuses ambient light entering the liquid crystal display device **100** so as to realize display in white close to paper white. Also, a portion of the light diffusion layer **30** formed in the transmission region **Tr** diffuses ambient light entering the liquid crystal display device **100** so as to suppress surface reflection in the transmission region **Tr** of the liquid crystal display device **100** and realize display free from unevenness and glare. Specifically, the portion of the light diffusion layer **30** formed in the transmission region **Tr** exhibits an anti-glare effect.

The light diffusion layer **30** may be selectively formed in the reflection region **Rf** alone as in the liquid crystal display device **100'** shown in FIG. **1B**. When the light diffusion layer **30** is thus formed, light transmitting the transmission region **Tr** is never diffused, resulting in improving optical efficiency. It may be appropriately selected depending upon the application of the liquid crystal display device whether or not the light diffusion layer **30** is formed in the transmission region **Tr**. The liquid crystal display device **100'** is different from the aforementioned liquid crystal display device **100** merely in the light diffusion layer **30** formed in the reflection region **Rf** alone, and hence, the description of the remaining structure is omitted.

As described above, the parallax derived from the thickness of the transparent substrate **9** can be suppressed by providing the light diffusion layer **30** on the surface of the transparent substrate **9** facing the liquid crystal layer **24**, so as to suppress blur of a displayed image.

The light diffusion layer **30** is preferably formed from a material obtained by dispersing, in a transparent matrix material (such as a resin of the acrylic family), a filler having a different refractive index from the matrix material. (Hereinafter, a light diffusion layer formed from such a material is designated as a "dispersion type light diffusion layer".) As compared with a light diffusion layer formed from a material obtained by roughening the surface of a thin film of a transparent material (such as an inorganic material like SiO_2) with a sandblaster or the like (hereinafter referred to as a "roughened light diffusion layer"), the dispersion type light diffusion layer is preferred because it can be easily formed in a uniform thickness and has a remarkable effect to suppress variation in the thickness of the liquid crystal layer **24**. Furthermore, in the dispersion type light diffusion layer **30** with a flat surface, the ratio of forward scattering to back scattering can be larger than in the roughened light diffusion layer having an irregular surface. Therefore, white light (that is, a phenomenon that the diffusion layer is visually recognized as a bright object) derived from back scattering can be suppressed, resulting in realizing bright display with a high contrast ratio.

The matrix material and the filler used for forming the dispersion type light diffusion layer **30** are preferably colorless and transparent. The light diffusion layer **30** provided on the surface of the transparent substrate **9** facing the liquid crystal layer **24** is subjected to a heat treatment process and a chemical treatment process during the fabrication of the liquid crystal display device **100** or **100'**, and hence, the matrix material and the filler are preferably sufficiently stable against these processes. Specifically, the matrix material and the filler preferably have heat resistance against heat of 200℃ or more and stability against water, alkalescency and chemicals such as isopropyl alcohol (IPA).

As the matrix material for the dispersion type light diffusion layer **30**, any of various polymers (such as resins of the polyester family, resins of the polyurethane family, epoxy resins, acrylic resins and amino resins) can be suitably used. In forming the light diffusion layer **30** selectively in the reflection region **Rf** as is shown in FIG. **1B**, it is preferred from the viewpoint of productivity that the light diffusion layer **30** formed on the entire surface is patterned by photolithography, and that a material with photosensitivity and a development property (etching property) is used.

The filler may be an inorganic filler such as silica or an organic filler such as polyimide and polysulfone. Furthermore, the filler is preferably in the form of particles with an average

particle size of 0.5 μm through 2.0 μm. When the average particle size is smaller than 0.5 μm, the light diffusing property may be spoiled, and when it exceeds 2.0 μm, the thickness of the light diffusion layer may be difficult to control or the surface flatness of the diffusion layer may be spoiled. The amount of the filler to be added depends also upon a difference in the refractive index from the matrix material and can be appropriately set so as to attain sufficient light diffusing property and light transmittance. When the amount is too large, although the light diffusing property of the light diffusion layer is improved, the light transmittance of the light diffusion layer itself is degraded. In order to realize sufficiently bright display, the transmittance (in a visible light region) of the light diffusion layer itself is preferably 90% or more. The thickness of the light diffusion layer is preferably in a range between 1 μm and 8 μm for attaining the sufficient light diffusing property. The aforementioned transmittance of the light diffusion layer is the transmittance of a light diffusion layer actually formed in this thickness. The transmittance is calculated as a percentage of a quantity of transmitted light, which is obtained by allowing perfect diffuse light to enter the light diffusion layer from the behind and receiving light having passed through the light diffusion layer in a normal line direction of the light diffusion layer at a collection angle of 2 degrees, to a quantity of incident light obtained without forming the light diffusion layer. The

transmittance can be measured with, for example, a luminance meter BM7 manufactured by TOPCON.

The light diffusion layer **30** can be formed by any of known methods of forming a thin film. For example, it can be formed by applying, on the substrate, a solution obtained by dissolving and dispersing the filler in the polymer by spin coating (coating method), or by adhering a dry film of the resin in which the filler is dispersed onto the substrate (film adhering method).

The light diffusion layer **30** can be provided in any of various positions. Now, the possible positions of the light diffusion layer **30** will be described with reference to FIGS. **3A** through **3C**.

The light diffusion layer **30** may be provided between a transparent substrate **40** and a color filter layer **42** as shown in FIG. **3A**, between the color filter layer **42** and a counter electrode **44** as shown in FIG. **3B**, or between the counter electrode **44** and an alignment layer **46** as shown in FIG. **3C**. Alternatively, in any of the three layered structures of FIGS. **3A** through **3C**, the color filter layer **42** and the counter electrode **44** can be replaced with each other.

Such a light diffusion layer **30** formed from the aforementioned dispersion type material can be easily formed to attain surface roughness (variation in thickness) 1/10 as small as the thickness of the liquid crystal layer (for example, 0.15 μm or less). The thickness of the liquid crystal layer depends upon the display mode (namely, the kind of liquid crystal material)

and is approximately 1.5 μm through 10 μm in general. Therefore, when such a dispersion type light diffusion layer is employed, a liquid crystal display device including a liquid crystal layer with a uniform thickness optimal to the display mode can be easily realized.

Furthermore, on the flat surface of the light diffusion layer **30** formed from the dispersion type material, scattering (back scattering) is minimally caused and light is effectively scattered (forward scattered) within the light diffusion layer **30**. As a result, display with a high contrast ratio can be realized in the reflection mode. Also, in the arrangement shown in FIG. **3C**, the light diffusion layer **30** can be used as an electric insulating layer. Specifically, the light diffusion layer **30** can be used as an overcoat layer formed between a driving electrode and an alignment layer in a STN liquid crystal display device or the like.

When the light diffusion layer **30** is disposed adjacent to (on or below) the color filter layer (typically having a thickness of 1 μm through 2 μm), substantially no parallax is caused between the color filter layer and the light diffusion layer, and hence, blur is never caused, resulting in realizing high quality display. Also, since there is no need to provide irregularities on the surface of a reflector plate, it is possible to suppress a phenomenon occurring in a conventional reflector plate having irregularities that interference between light reflected by the irregularities becomes conspicuous through an anti-glare film so as to be observed

as uneven display.

Now, control of the thickness of the liquid crystal layer **24** (also designated as a "cell gap") in the liquid crystal display device **100** or **100'** will be described.

A thickness **dr** of the liquid crystal layer **24** in the reflection region **Rf** of the liquid crystal display device **100** or **100'** is set to be 1/2 of a thickness **dt** of the liquid crystal layer **24** in the transmission region **Tr**. Ambient light used for display in the reflection mode enters from above in FIG. **1A** or **1B** (through the counter substrate **100B** or **100B'**), passes through the liquid crystal layer **24**, is reflected by the metal layer **23**, passes through the liquid crystal layer **24** again and goes out through the counter substrate **100B** or **100B'**, and thus passes the liquid crystal layer **24** twice. Accordingly, by setting the thickness **dr** of the liquid crystal layer **24** in the reflection region **Rf** to 1/2 of the thickness **dt** of the liquid crystal layer **24** in the transmission region **Tr**, the optical path length of light used for display in the reflection mode can accord with the optical path length of light used for display in the transmission mode. In a mode where the polarization direction is changed (rotated) by the liquid crystal layer **24** (such as the TN mode, the STN mode and the ECB mode including the vertical alignment mode), high quality display can be realized by making the polarization direction of light having passed through the reflection region **Rf** accord with the polarization direction of light having passed through the transmission region **Tr** in each

pixel region **Px**.

In order to sufficiently satisfy the condition for the thicknesses of the liquid crystal layer **24**, the thicknesses **dt** and **dr** of the liquid crystal layer **24** are preferably constant in the transmission region **Tr** and the reflection region **Rf**, respectively. The active matrix substrate **100A** included in the present liquid crystal display device **100** or **100'** has the flat surfaces facing the liquid crystal layer **24** in the transparent electrode region **20** and the reflection electrode region **22** as described above, and the light diffusion layer **30** provided on the counter substrate **100B** or **100B'** also has a flat surface facing the liquid crystal layer **24**. Therefore, the thicknesses of the liquid crystal layer **24** are respectively constant in the transmission region **Tr** and the reflection region **Rf**, so as to realize high quality display.

Specifically, variation in the thickness of the liquid crystal layer **24** in the transmission region **Tr** and the reflection region **Rf** in the present liquid crystal display device **100** or **100'** is as small as 0.03 through 0.05 in the standard deviation σ (obtained by measuring the thicknesses at 25 points on the plane). On the other hand, the variation in the thickness of the liquid crystal layer in the reflection region in the liquid crystal display device using the reflection electrode with an irregular surface disclosed in Japanese Laid-Open Patent Publication No. 11-101992 is as large as 0.12 through 0.15 in the standard deviation σ and

sometimes exceeds 1/10 of the thickness of the liquid crystal layer. As is obvious from this fact, the transmission/reflection type liquid crystal display devices **100** and **100'** of this invention can realize higher quality display than the conventional display device.

Now, a method of controlling the thickness (cell gap) of the liquid crystal layer **24** in a liquid crystal display device **200** and **200'** according to this invention will be described with reference to FIGS. **4A** and **4B**.

The liquid crystal display devices **200** and **200'** are respectively different from the liquid crystal display devices **100** and **100'** in including an insulating film **48** and a metal layer **23'** formed thereon instead of the metal layer **23** formed on the active matrix substrate **100A** shown in FIGS. **1A** and **1B**. The other composing elements of the liquid crystal display devices **200** and **200'** are substantially the same as those of the liquid crystal display devices **100** and **100'**, respectively, and hence, the description is omitted by using like reference numerals to refer to like elements.

In the case where the light diffusion layer **30** is formed on substantially the entire surface of the counter substrate **100B** as in the liquid crystal display device **200** of FIG. **4A**, as is shown in formula (1) below, the thickness **dr** (= **D2**) of the liquid crystal layer **24** in the reflection region **Rf** can be set to 1/2 of the thickness **dt** of the liquid crystal layer **24** in the transmission region **Tr**

by equalizing the thickness (**D1**) of the insulating layer **48** to the diameter (**D2**) of a spacer **52**. The thickness of the metal layer **23'** is negligible because it is very thin as compared with the insulating layer **48**.

$$D1 + D2 = dt \quad (D1 = D2 = dr) \quad \ldots \quad (1)$$

On the other hand, in the case where the light diffusion layer **30** is selectively formed in the reflection region **Rf** alone as in the liquid crystal display device **200'** of FIG. **4B**, as is shown in formula (2) below, the thickness **dr** (= **D2**) of the liquid crystal layer **24** in the reflection region **Rf** can be set to 1/2 of the thickness **dt** of the liquid crystal layer **24** in the transmission region **Tr** by equalizing the diameter **D2** of the spacer **52** to the sum of the thickness **D1'** of the insulating layer **48** and the thickness **D3** of the light diffusion layer **30**.

$$D1' + D2 + D3 = dt \quad (D1' + D3 = D2 = dr) \quad \ldots \quad (2)$$

The aforementioned relationship is an optimal relationship in the design, and hence may not be satisfied in actual fabrication of a liquid crystal cell due to influence of processing accuracy. However, when the thickness **dr** of the liquid crystal layer **24** in the reflection region **Rf** and the thickness **dt** of the liquid crystal layer **24** in the transmission region **Tr** are shifted by 15% or less of the design values, the display quality can be improved as compared with that attained by the conventional display device.

Now, other examples of the structures of the light diffusion layer **30** and the reflection electrode region **22** usable in the liquid

crystal display device of this embodiment will be described. The reflection electrode region **22** can be formed from a single metal layer **23** or formed from the insulating layer **48** and the metal layer **23'** formed thereon as is exemplified in the liquid crystal display devices **100** and **200** of Embodiment 1. In these cases, the thickness of the liquid crystal layer **24** in the reflection region **Rf** can be adjusted by controlling the thicknesses of the metal layer **23** and the insulating layer **48**, respectively. In the following description, the detailed structures of the transparent electrode region **20** and the reflection electrode region **22** are omitted for simplification. Also, in the drawings referred to in the following description, the same reference numerals are used to refer to elements having substantially the same functions as those of the aforementioned liquid crystal display devices of Embodiment 1 so as to omit the description.

In a liquid crystal display device **300** of FIG. **5**, the light diffusion layer **30** is selectively formed in the reflection region **Rf** alone as in the liquid crystal display device **100'** of FIG. **1B**, whereas the thickness of the liquid crystal layer **24** in the reflection region **Rf** is adjusted by controlling the thickness of the light diffusion layer **30**. Since the light diffusion layer **30** is not formed in the transmission region **Tr** in the liquid crystal display device **300** as in the liquid crystal display device **100'**, optical loss caused through diffusion of light passing through the transmission region **Tr** can be avoided, so as to improve the

optical efficiency.

A liquid crystal display device **400** of FIG. **6** includes the light diffusion layer **30** selectively formed in the reflection region **Rf** and a transparent layer **54** selectively formed in the transmission region **Tr**. The transparent layer **54** has the same thickness as the light diffusion layer **30** and has a flat surface. The color filter layer **10** is formed on the flat face formed by the light diffusion layer **30** and the transparent layer **54**. The thickness of the liquid crystal layer **24** in the reflection region **Rf** is adjusted by controlling the thickness of the reflection electrode region **22**. The transparent layer **54** may be formed from, for example, an acrylic resin or a polyimide resin similarly to the matrix material for the dispersion type light diffusion layer. This structure is advantageous because the thickness of the liquid crystal layer can be comparatively easily controlled owing to the flatness of the surface, facing the liquid crystal layer, of the substrate bearing the light diffusion layer (namely, the substrate closer to an observer).

A liquid crystal display device **500** of FIG. **7** includes a color filter layer **60** having a light diffusion color filter region **60a** with a function to diffuse light and a general color filter region **60b**. The light diffusion color filter region **60a** is selectively provided correspondingly to the reflection region **Rf**. Since the light diffusing function is thus provided to a part of the color filter layer **60**, the entire structure can be simplified.

The light diffusion color filter region **60a** can be formed from a material obtained by dispersing a filler having a different refractive index in a material for forming the general color filter layer. For example, when a color filter layer with a thickness of approximately 1.7 μm is formed from a dispersion type material obtained by adding 30 wt% of a filler in the form of particles (such as silica) with a particle size of 1 μm to a general material for a color filter layer, the light diffusion color filter region **60a** can be formed. The light diffusion color filter region **60a** has surface smoothness and thickness uniformity equivalent to those of the color filter region **60b** where no filler is dispersed.

Needless to say, a color filter layer **60'** including the light diffusion color filter region **60a** on substantially the entire surface can be provided on the counter substrate as in a liquid crystal display device **600** of FIG. **8**. It is appropriately determined depending upon the application of the liquid crystal display device whether the light diffusion color filter region **60a** is selectively formed in the reflection region **Rf** alone or formed on the entire surface similarly to the determination regarding the light diffusion layer **30**.

In a liquid crystal display device **700** of FIG. **9**, a glass substrate **62** of the counter substrate has an irregular surface (light diffusion layer) **64**. Random irregularities are selectively formed in a portion corresponding to the reflection region **Rf** on the surface of the glass substrate (for example, #1737;

manufactured by Corning Inc.). The random irregularities can be formed by, for example, sandblast. The irregularities formed by the sandblast have a size on the plane (that can be approximated to the diameter) of approximately 2 through 5 μm, and a depth of approximately 0.5 through 1 μm, and their centers are randomly distributed on the plane. Furthermore, when a planarizing film (of, for example, SiO_2) having a refractive index different from the glass substrate **62** is formed on the glass substrate **62** having the irregular surface, the ability to diffuse light can be improved. In such a structure, the irregular surface of the glass substrate **62** or the combination of the irregular surface and the planarizing film (not shown) functions as the light diffusion layer. Although the light diffusion layer **64** is selectively formed in the reflection region **Rf** in FIG. **9**, the light diffusion layer **64** may be formed on substantially the entire surface of the substrate as in the aforementioned structures. Furthermore, the glass substrate **62** may be replaced with a plastic substrate.

Moreover, when a plastic substrate **70** with a polarization function is used as in a liquid crystal display device **800** of FIG. **10**, the polarizing plate (not shown) on the side of the counter substrate can be omitted so as to simplify the structure. The plastic substrate **70** occasionally has retardation derived from its fabrication method, and hence, the retardation (phase difference) of the plastic substrate is preferably as small as possible from the viewpoint of the contrast ratio. The liquid

crystal display device **800** has the same structure as the liquid crystal display device **100** of Embodiment 1 except for the plastic substrate **70** with the polarization function. The plastic substrate **70** with the polarization function may be used in any of the aforementioned liquid crystal display devices.

A transparent insulating substrate used in the counter substrate may have a light diffusing function as in a liquid crystal display device **900** of FIG. **11**. A plastic substrate **80** of the liquid crystal display device **900** is formed from a polymer material where a filler is dispersed and has a light diffusing function. The plastic substrate **800** is formed from, for example, a material obtained by dispersing 15 through 20 wt% of a silica filler in the form of particles (with an average particle size of 1 μm) in PET or PES (a matrix material).

In each of the liquid crystal display devices of FIGS. **7** through **9** and **11**, there is no need to separately form a light diffusion layer. Therefore, they have advantages that the fabrication process can be simplified (namely, the fabrication cost can be reduced) and that the thickness can be further reduced in addition to the above-described advantages of the liquid crystal display devices of this embodiment. Also, when the plastic substrate with the polarization function is used as in the liquid crystal display device **800** of FIG. **10**, one polarizing plate can be omitted, so as to further simplify the fabrication process and further reduce the thickness of the liquid crystal display device.

EMBODIMENT 2

A liquid crystal display device according to Embodiment 2 is different from the liquid crystal display devices of Embodiment 1 in including a light diffusion layer disposed on the outside of a second substrate (a side closer to an observer) opposing a first substrate (closer to a back light) with a liquid crystal layer sandwiched therebetween. In drawings showing liquid crystal display devices of Embodiment 2, the same reference numerals are used to refer to elements substantially having the same functions as those used in the liquid crystal display devices of Embodiment 1 so as to omit the description.

FIGS. **12A** and **12B** respectively show the schematic sectional structures of the liquid crystal display devices **1000** and **1000'** of Embodiment 2. The liquid crystal display devices **1000** and **1000'** of FIGS. **12A** and **12B** are respectively different from the liquid crystal display devices **200** and **200'** of FIGS. **4A** and **4B** in disposing the light diffusion layer **30** on the outside (a side closer to an observer) of the transparent substrate **9**.

When the light diffusion layer **30** is selectively formed correspondingly to the reflection region **Rf** on the outside of the transparent substrate **9** as is shown in FIG. **12B**, the light diffusion layer **30** is preferably slightly larger than the reflection region **Rf**. Specifically, the area of the light diffusion layer **30** is preferably increased in accordance with a distance between the light diffusion layer **30** and a metal layer (reflection layer) **23'**

increased by a dimension corresponding to the thickness of the transparent substrate **9** (of, for example, 0.7 mm), so as to allow most of light obliquely entering the metal layer **23'** or most of light obliquely going out from the metal layer **23'** to pass through the light diffusion layer **30**. The area of the light diffusion layer **30** provided correspondingly to the reflection region **Rf** can be appropriately set also in consideration of the liquid crystal display mode and the like.

The liquid crystal display devices **1000** and **1000'** are more advantageous than the liquid crystal display devices **200** and **200'** of Embodiment 1 each including the light diffusion layer **30** on the inside of the transparent substrate **9** in easiness in the fabrication, applicability to design change or common use of the light diffusion layer and low fabrication cost. Specifically, the light diffusion layer **30** is formed on the outside of the transparent substrate **9** after adhesion of the substrates **100A** and **100B** and injection of a liquid crystal, and therefore, the yield can be avoided from lowering due to the formation of the light diffusion layer **30**. Also, although the light diffusion layer **30** may be formed by any of various methods as in Embodiment 1, it is preferable to use the light diffusion layer **30** formed from a film. The film for forming the light diffusion layer can be commonly used among liquid crystal display devices of various types (for example, having different panel sizes), and the film can be used flexibly in case of a change in the design of the liquid crystal

display device.

The effect to simplify the fabrication (namely, the effect to decrease the cost) is more remarkable in the structure where the light diffusion layer **30** is formed on the entire display region as in the liquid crystal display device **1000** than in the structure where the light diffusion layer **30** is selectively formed as in the liquid crystal display device **1000'**. In particular, in a liquid crystal display device **1100** of FIG. **13** including a pair of polarizing plates **90a** and **90b**, when a material having a light diffusing function is used an adhesive for adhering the polarizing plate **90a** onto the outside of the transparent substrate **9**, a light diffusion layer **30a** can be used also as the adhesive layer, resulting in further simplifying the fabrication process. Furthermore, also for the purpose of suppressing blur of a displayed image, the light diffusion layer **30** is preferably adjacent to the transparent substrate **9**. Therefore, also from the viewpoint of suppressing blur of a displayed image, the light diffusion layer **30a** is effectively used as the adhesive layer between the polarizing plate **90a** and the transparent substrate **9**.

As the material for the light diffusion layer also serving as the adhesive, a dispersion type material obtained by adding a filler to any of various resin adhesives (working as a matrix material) can be suitably used. Examples of the resin adhesives are adhesives of the phenol family, the acrylic family, the polyimide family, the epoxy family and the silicon family. As

the filler, any of the fillers for the dispersion type light diffusion layer described in Embodiment 1 can be widely used.

FIG. **14** is a schematic sectional view of another liquid crystal display device **1200** of this embodiment. In the liquid crystal display device **1200**, the light diffusion layer **64** (irregular surface) of the liquid crystal display device **700** of FIG. **9** described in Embodiment 1 is formed on the outside of a glass substrate **62**. The liquid crystal display device **1200** can be fabricated by substantially the same method as the liquid crystal display device **700**.

In the structure where the light diffusion layer **64** is selectively formed correspondingly to the reflection region **Rf** as is shown in FIG. **14**, the light diffusion layer **64** is preferably larger than the reflection region **Rf** similarly to the light diffusion layer **30** of the liquid crystal display device **1000**' of FIG. **12B**.

Furthermore, the ability to diffuse light can be improved when a planarizing film (of, for example, SiO_2) having a different refractive index from the glass substrate **62** is formed on the glass substrate **62** having the irregular surface. In such a structure, the irregular surface of the glass substrate **62** or the combination of the irregular surface and the planarizing film (not shown) functions as the light diffusion layer. In the structure where a polarizing plate is disposed on the outside of the glass substrate **62**, when a transparent material having a different refractive index

from the glass substrate **62** is used as a material for an adhesive layer for adhering the polarizing plate (not shown) onto the outside of the glass substrate **62**, the adhesive layer can function as the planarizing film.

Although the light diffusion layer **64** is selectively formed correspondingly to the reflection region **Rf** in FIG. **14**, the light diffusion layer **64** can be formed on substantially the entire surface of the substrate as in the aforementioned structures. Also, the glass substrate **62** can be replaced with a plastic substrate.

EMBODIMENT 3

A liquid crystal display device according to Embodiment 3 is similar to the liquid crystal display devices of Embodiment 2 in disposing a light diffusion layer on the outside (a side closer to an observer) of a second substrate (closer to the observer), but is different in further including an anti-glare layer on the outside of the second substrate. In drawings showing liquid crystal display devices of Embodiment 3, the same reference numerals are used to refer to elements having substantially the same functions as those of the liquid crystal display devices of Embodiment 1 and 2 so as to omit the description. Also, detailed description of the structures of the transparent electrode region **20** and the reflection electrode region **22** is omitted for simplification.

FIG. **15** is a schematic sectional view of a liquid crystal display device **1300** of Embodiment 3. The liquid crystal display

device **1300** of FIG. **15** is obtained by providing an anti-glare layer **94** on the surface closer to an observer of the liquid crystal display device **1000** of FIG. **12A**.

The anti-glare layer **94** formed on the surface closer to an observer of the liquid crystal display device **1300** of Embodiment 3 is formed from a transparent material and has irregularities on its surface. The anti-glare layer **94** diffusedly reflects (scatters) ambient light mainly entering from the side closer to the observer. As a result, mirror reflection (direct reflection) of ambient light on the surface closer to the observer of the liquid crystal display device **1300** can be suppressed, so as to realize display with good visibility free from reflection of ambient images.

The anti-glare layer **94** is formed from, for example, AGS1 or AG30 manufactured by Nitto Denko Corporation. The optical characteristic of the anti-glare layer **94** is set in accordance with a desired anti-glare effect, and the pitch of the irregularities (average distance between the irregularities) of the anti-glare layer **94** is distributed to some extent within a range between approximately 30 μm and approximately 150 μm. For example, the pitches of the irregularities of the aforementioned products of Nitto Denko Corporation are distributed between approximately 47 μm and approximately 52 μm in AGS1 and between approximately 95 μm and approximately 140 μm in AG30.

In the case where the aforementioned anti-glare layer for

realizing good display is provided in a liquid crystal display device having a conventional structure, in particular, in a liquid crystal display device having a pixel pitch (either the lateral pitch or longitudinal pitch) of approximately 120 μm or less, the display is sometimes uneven. Since such display failure is more conspicuous as ambient light is more intense, the display quality is lower in use in the open air in fine weather.

The present inventors have found that the display failure derives from moiré caused between the anti-glare layer having the irregularities and plural pixel regions arranged in a matrix. Moiré occurs due to light interference caused when plural periodic structures are overlapped.

The display failure is caused in both a transmission type liquid crystal display device and a reflection type liquid crystal display device, but is more conspicuous in a transmission/reflection type liquid crystal display device having a transmission region for the transmission mode display and a reflection region for the reflection mode display in each pixel region. The reason is as follows:

In a transmission/reflection type liquid crystal display device, each pixel region includes a transmission region and a reflection region, and hence, not only plural pixel regions are arranged in a periodic pattern but also plural transmission regions and plural reflection regions are also respectively arranged in periodic patterns. Accordingly, moiré is caused by the

irregularities of the anti-glare layer, the pixel regions, the transmission regions and the reflection regions, resulting in causing conspicuous display failure. The display failure is more conspicuous when a difference between the pitch of the irregularities of the anti-glare layer and the pitch of the periodic structure is smaller.

In the liquid crystal display device **1300** of this embodiment, the counter substrate **100B** includes the light diffusion layer **30**, and hence, paper white display can be realized as in the liquid crystal display devices of Embodiments 1 and 2. Furthermore, the light diffusion layer **30** suppresses the occurrence of the above-described moiré, so that the display can be free from unevenness.

Specifically, since the light diffusion layer **30** is provided on the counter substrate **100B** in the liquid crystal display device **1300**, both light entering from the back light and passing through the transmission region **Tr** and light entering from the side closer to an observer, reflected by the reflection electrode region **22** and passing through the reflection region **Rf** pass through the light diffusion layer **30** so as to be diffused by the light diffusion layer **30** before going out toward the observer. Accordingly, moiré caused between the irregularities of the anti-glare layer **94** and the pixel regions **Px**, moiré caused between the irregularities of the anti-glare layer **94** and the transmission regions **Tr** and moiré caused between the irregularities of the anti-glare layer **94** and

the reflection regions **Rf** are all suppressed, resulting in realizing display free from unevenness.

The effect to suppress the occurrence of moiré is more remarkable in the structure where the light diffusion layer **30** is provided on the outside (a side closer to an observer) of the counter substrate **100B** as in the liquid crystal display device **1300** of FIG. **15** than in the structure where the light diffusion layer **30** is provided on the inside (a side closer to the liquid crystal layer) of the counter substrate **100B**. Furthermore, the light diffusion layer **30** is formed preferably on the entire surface of the counter substrate **100B** for suppressing the occurrence of moiré.

Moreover, in a liquid crystal display device **1400** of FIG. **16** including a pair of polarizing plates **90a** and **90b**, in order to suppress blur of a displayed image, the light diffusion layer **30** is preferably provided between the polarizing plate **90a** disposed on the outside of the transparent substrate **9** and the transparent substrate **9**. In addition, from the viewpoint of simplification of the fabrication process, the light diffusion layer **30** preferably also serves as an adhesive layer for adhering the polarizing plate **90a** to the transparent substrate **9**.

Also in any of the liquid crystal display devices of this embodiment, the arrangement of the transmission region **Tr** and the reflection region **Rf** in the pixel region **Px** can be appropriately set in accordance with the specification of the liquid crystal

display device. Now, examples of the arrangement of the transmission region **Tr** and the reflection region **Rf** and periodic structures causing the moiré in the exemplified arrangement will be described.

First, as is shown in FIG. **17**, the transmission region **Tr** may be provided at the center of the pixel region **Px** with the reflection region **Rf** surrounding the transmission region **Tr**. In this arrangement, along the longitudinal (lengthwise) direction of the pixel regions **Px**, there are a periodic structure where the pixel regions **Px** are arranged in a predetermined pixel pitch, a periodic structure where the transmission regions **Tr** each having a predetermined width $\mathbf{T_1}$ are arranged at a predetermined interval $\mathbf{T_2}$, and a periodic structure where the reflection regions **Rf** each having a predetermined width $\mathbf{R_1}$ are arranged at a predetermined interval $\mathbf{R_2}$. Also, along the lateral (widthwise) direction of the pixel regions **Px**, there are similar plural periodic structures. Table 1 below shows exemplified values of dimensions indicated with reference characters **a** through **h** in FIG. **17**. The values listed in Table 1 are values in a 2-inch type liquid crystal panel where the area ratio between the reflection region **Rf** and the transmission region **Tr** is 9:1.

Table 1:

	a	b	c	d	e	f	g	h
Width (μm)	68	31	28	28	68	45	59	138

Alternatively, as is shown in FIG. **18**, the transmission region **Tr** may be provided with its one side defining its outline overlapping one side of the pixel region **Px** defining its outline, with the reflection region **Rf** provided in a U-shape surrounding the transmission region **Tr**. Also in this arrangement, there are plural periodic structures respectively along the longitudinal and lateral directions of the pixel regions **Px**. Table 2 shows exemplified values of dimensions indicated with reference characters **a'** through **g'** in FIG. **18**. The values listed in Table 2 are values in a 2-inch type liquid crystal panel where the area ratio between the reflection region **Rf** and the transmission region **Tr** is 6:4 or 8:2.

Table 2:

In the case where the area ratio is 6:4:

	a'	b'	c'	d'	e'	f'	g'
Width (μm)	53	44	24	24	50	112	71

In the case where the area ratio is 8:2:

	a'	b'	c'	d'	e'	f'	g'
Width (μm)	62	51	27	27	146	135	188

Alternatively, plural transmission regions **Tr** may be formed within each pixel region **Px** as is shown in FIG. **19**. In this case, along the longitudinal direction of the pixel regions **Px**, there are a periodic structure where the pixel regions **Px** are arranged in a predetermined pixel pitch, a periodic structure where the transmission regions **Tr** each having a predetermined width $\mathbf{T_1}$ are arranged at predetermined intervals $\mathbf{T_2}$ and $\mathbf{T_2}$' alternately, and

a periodic structure where the reflection regions **Rf** each having a predetermined width $\mathbf{R_1}$ are arranged at a predetermined interval $\mathbf{R_2}$. Also, along the lateral direction of the pixel regions **Px**, there are plural periodic structures. Table 3 shows exemplified values of dimensions indicated with reference characters **a''** through **g''** in FIG. **19**. The values listed in Table 3 are values in a 3.5-inch type liquid crystal panel where the area ratio between the reflection region **Rf** and the transmission region **Tr** is 3:7, 5:5 or 8:2.

Table 3:

In the case where the area ratio is 3:7:

	a''	b''	c''	d''	e''	f''	g''
Width (μm)	34	80	14	14	115	50	40

In the case where the area ratio is 5:5:

	a''	b''	c''	d''	e''	f''	g''
Width (μm)	59	55	26	26	114	49	40

In the case where the area ratio is 8:2

	a''	b''	c''	d''	e''	f''	g''
Width (μm)	85	28	39	39	114	50	40

In the liquid crystal display devices **1300** and **1400** of this embodiment, moiré caused between the plural periodic structures as exemplified above and the periodic structure of the irregularities of the anti-glare layer **94** can be suppressed, resulting in realizing display free from unevenness.

The combination of an active matrix substrate and a counter

substrate can be appropriately selected among those included in the liquid crystal display devices described in the embodiments. Furthermore, active matrix liquid crystal display devices using TFTs (thin film transistors) are described in the embodiments, which does not limit the invention. The invention is applicable to any other liquid crystal display device such as an active matrix liquid crystal display device using MIM elements and a passive matrix liquid crystal display device.